

## On the ecological significance of two predators of *Metatetranychus ulmi* C. L. Koch (Acari, Tetranychidae)

by

Dr D. J. KUENEN

(Laboratorium van Zeelands Proeftuin, Wilhelminadorp, Z.)

*Metatetranychus ulmi* Koch (Acari, Tetranychidae) is a common pest of fruit trees, occurring in the temperate zone, most damage being done to apple and plum. From 1941 onwards I have been studying the bionomics of this mite and a general account on its ecology and control will appear shortly.

In the following a special aspect of the problem will be discussed, namely the influence of certain predators on the abundance of the mite and vice versa. Predators are certainly not the most important of the factors influencing the abundance of the mite, but under certain conditions their influence can be very great.

Of particular interest was the situation which developed in 1943 on three varieties of plum on which regular counts of the mite and its predators were made. Of the 30 predators of the Fruit Tree Red Spider which are known from all over the world about 8 occur in the Netherlands, but only 2 were found on the plums that year. This was a great simplification of the situation and the community on the leaf can be considered to have only consisted of the following 3 species.

A : *Metatetranychus ulmi* (prey)

B : *Scymnus minimus* (predator)

C : *Typhlodromus similis* Koch (predator)

A. *Metatetranychus ulmi* (= *Paratetranychus pilosus* C. & F.)

This mite, commonly known as the Fruit Tree Red Spider, which is to all practical purpose cosmopolitan, occurs mainly on fruit trees (specially apple and plum) and feeds on the contents of the parenchymatic cells. Locally the damage done by this mite can be very serious. The animal hibernates as egg on the twigs of the trees. In spring the larvae migrate to the young leaves, where they develop and attain maturity in about 4 weeks time. After copulation the females deposit their eggs on the leaves and after 8—10 days the larvae of the second generation emerge. In the Netherlands' climate 3—5 generations develop in one year, dependant upon different circumstances. In the autumn the females migrate to the twigs where they deposit their winter eggs.

There are many factors which influence the population-density of this mite : climate, food (dependant upon variety, growth and

treatment of the tree), predators (parasites have nowhere been recorded) and in the commercial orchard also spraying. In another publication some details of these influences will be treated more extensively. In this paper we will mainly consider the effect of the two predators.

### *B. Scymnus minimus* Payk.

This small Coccinellid beetle hibernates as adult. The animal is entirely black, the larvae are brown with black markings. The females deposit their whitish eggs in May and the beginning of June on leaves on which the mites occur. The larvae which hatch from these eggs feed exclusively on Tetranychidae. They attack all stages of *M. ulmi* including the eggs. In about a month and a half they are full grown and pupate on the lower surface of the leaf. The adults, which emerge about the end of July or the beginning of August start a second generation. The adults of this generation hibernate.

The amount of food consumed has been estimated by different authors. The value of such estimations will be discussed later. The data from literature are tabulated below. Those on *Stethorus picipes*, which is very closely related and to the ecologist seems practically identical, have been included.

Species	Author	Locality	Time of observation	Stage	Numbers consumed
Stethorus picipes	Newcomer & Yothers 1929 Gilliat (1935)	U.S.A.	1 hour	larva	4 mites
			30 days	"	300-400 m.
		Canada	1 hour	"	8-10 m. + eggs
			"	adult	11 m. + e
Scymnus minimus	Listo (1939)	Finland	"	larva	9 m.
			"	adult	25 m.
	Geyskes (1938) Kuenen	Netherlands	"	larva	24 m.
		"	"	"	4 m. + 16 e

Table 1.

In this table data on the adults have been included. They are found only occasionally on the leaves, and have much less significance as predators than the larvae.

### *C. Typhlodromus similis* Koch and *T. spec.*<sup>1)</sup>

Like the beetle these two species of mites hibernate as adults. The unidentified species is much less abundant. They are treated here as one single species as no difference between the behaviour of the two was found.

In spring they emerge from their hiding-places and go to the leaves where they feed on the mites only. No eggs of *M. ulmi* are ever eaten. The eggs which can be found regularly during the summer, are deposited on the lower surface of the leaf, and are pale

<sup>1)</sup> The identification was kindly performed by Mr. G. L. van Eynhoven, Haarlem.

yellow and transparent. Only very little is known about the biology of these species. There is certainly more than one generation per year.

Of a closely related species an estimate has been made of the amount of food consumed by Gilliat (1935), who mentions that the species *Seiulus pomi* Parrott consumed an average of 1.91 mites daily. No further data on the food consumption of these predacious mites have been published.

In the following table (2) the data are given of three different populations of the mite with the two predators occurring amongst them. These data have been obtained in the following way.

For the study of the factors influencing the population-density of *M. ulmi*, counts were made of the numbers of mites on certain trees for several years in succession. To this end 100 leaves were picked from each of the trees under observation every week and the numbers of mites (and other animals including predators) were counted under a binocular microscope ( $\times 10$ ). By calculating the error in the final data and by check-countings it was shown that sufficient accuracy was thus obtained.

The counts given here were made in 1943 on three varieties of plums (on the same rootstock) and the numbers give the totals per 100 leaves. The extent of infestation with *M. ulmi* may be considered to be moderate. In 1942 numbers of over 10,000 mites per 100 leaves were found on the variety „Monarch”. The number of predacious mites the largest found in 4 years of investigation.

The successive generations of *M. ulmi* can be easily followed in the table. Each maximum of mites is followed by a maximum of eggs and so on. To make it more clear all maxima have been underlined.

The population develops to a different extent on the different varieties, the most on "Monarch" (Mon.), less on "Gele Heerenpruim" (G.H.P.), and least on "Reine Claude d'Hoefer" (R.C.H.). Except for the first generation this can be seen all through the year. It is not dependant upon the predators, though these have some influence upon it, or upon the size of the initial population, but it is caused by the difference in food on the different varieties, which influences the reproductive capacity.

The counts began on May 3rd. Before then there were practically no leaves on the trees yet. Towards the end of August the population begins to diminish. By comparison with the development on other trees it was shown that the climate was still favourable for further development of the next generation. The decrease of the population at this early date was therefore due to conditions on the plum trees, and was caused, as will be shown presently by the abundance of predators. After October 11th there were practically no leaves on the trees.

Dat.	MONARCH (Mon.)							GELE HEERENPRUIM (G.H.P.)							REINE CLAUDE D'HOEFER (R.C.H.)						
	M. ulmi			S. min.				M. ulmi			S. min.				M. ulmi			S. min.			
	m	e	e	l	p	i	T.	m	e	e	l	p	i	T.	m	e	e	l	p	i	T.
3 May	161	—	—	—	—	—	3	229	—	—	—	—	—	—	59	—	—	—	—	—	3
10 "	325	—	—	—	—	—	—	369	—	—	—	—	—	—	102	—	—	—	—	—	2
17 "	246	5	—	—	—	—	—	309	20	—	—	—	—	—	41	9	—	—	—	—	1
26 "	110	322	3	—	—	—	—	85	472	7	—	—	—	—	16	224	5	—	—	—	—
31 "	50	400	1	—	—	—	1	26	600	4	—	—	—	—	3	287	2	—	—	—	3
7 June	48	821	1	—	—	—	3	70	669	3	1	—	—	—	24	339	5	2	—	—	3
15 "	340	582	2	—	—	—	1	277	285	10	3	—	—	—	38	86	2	3	—	—	2
23 "	283	186	2	4	—	—	7	307	130	4	3	—	—	—	41	33	1	1	—	—	8
28 "	191	342	4	1	—	—	—	173	407	8	2	—	—	4	29	65	—	—	—	—	5
5 July	193	1034	5	3	—	—	—	76	764	9	5	—	—	2	7	146	—	—	—	—	5
13 "	245	1733	3	—	—	—	6	181	1020	6	—	1	—	3	30	269	—	—	—	—	5
19 "	463	1498	5	10	1	—	3	403	598	2	4	—	—	4	54	89	—	—	—	—	14
26 "	559	781	4	7	—	—	2	255	361	1	3	—	—	11	17	26	—	—	—	—	17
2 Aug.	364	2191	1	—	2	—	16	206	1283	—	1	1	—	23	9	339	—	—	—	—	30
10/11 "	280	2273	2	3	—	—	41	529	1319	3	1	—	1	115	23	201	2	—	—	—	48
16 "	982	1694	4	4	—	—	82	434	858	—	—	—	—	102	36	144	—	—	—	—	70
23 "	500	1292	2	6	—	1	152	164	248	—	2	—	—	102	6	20	—	—	—	—	40
31 "	148	1036	—	2	—	—	188	74	618	—	—	—	2	268	4	28	—	—	—	—	48
6 Sept.	140	564	—	—	2	—	126	16	118	—	—	—	—	146	2	22	—	—	—	—	80
13 "	74	96	—	—	—	—	210	20	40	—	—	—	—	298	—	6	—	—	—	—	92
20 "	6	4	—	—	—	—	276	—	—	—	—	—	—	260	—	—	—	—	—	—	82
11 Oct.	—	6	—	—	—	—	28	2	—	—	—	—	—	30	8	—	—	—	—	—	—

Table 2.

Monarch, Gele Heerenpruim, Reine Claude d'Hoefer are three plum-varieties. M. ulmi = Metatetranychus ulmi (with m = mites; e = eggs); S. min. = Scymnus minimus (with: e = eggs; l = larvae; p = pupa; i = adults), T = Typhlodromus spp.

As regards *Sc. minimus* we can see that eggs are deposited on all three varieties. At first the number of eggs bears no obvious relation to the number of mites (prey) present. In the beginning of June the larvae have hatched and directly a difference between the trees is evident. On the R.C.H., where there are the smallest number of prey, all larvae die within a short time so that after June 23rd no more are to be found. On the others a considerable population of larvae develops. From July 13th onwards pupae are occasionally found. Apparently, at least part of the larvae have found sufficient food to complete their development. After that, however, a clear difference between G.H.P. and Mon. develops. In August only few larvae are left on the G.H.P., but no pupae can be found; on Mon. a larger number of larvae and in September even 2 pupae of the next generation. The number of eggs deposited is also much larger on Mon., which may be due to better food conditions for the adults. Because of the larger number of eggs the generations are less clearly separated on this variety than on the other varieties.

On the R.C.H. too eggs of the second generation are deposited but no further larvae have been found on this variety.

We thus see that there is a clear relation between the abundance of the prey and the number of predators we find on the different varieties. The more numerous the prey, the better the development of the predator.

*Typhlodromus* remains rather scarce up to the end of July, but in the beginning of August there is a change. On all three varieties a strong increase sets in which continues up to the middle of September. After that there follows an abrupt decrease of numbers.

On R.C.H. the increase is less than on the other varieties. From this it seems probable that there is some relation between the abundance of prey and predator.

However, after the decrease of the prey the predator goes on increasing in number, only when the number of prey is reduced to practically zero, the predators begin to decrease. If we now compare the trend of the population of the two different predators, in connection with the abundance of the prey, we see the following.

The population of *M. ulmi* goes on increasing in spite of the presence of beetle-larvae and predacious mites. The beginning of the strong increase in the predacious mites coincides with the decrease of the prey. As we know from observations on other trees at the same time, climatic conditions were still favourable for the development of yet another generation of mites; furthermore there was definitely no shortness of food for *M. ulmi*, the leaves were still green and other studies have shown that only browning of the leaves means reduction of food to the extent of reducing the population. It can therefore be assumed that the reduction in numbers does not only coincide in time with, but is actually caused by the activity of the predacious mite.

Now the number of predacious mites was very large and one might suggest that a larger number of beetle-larvae could have done the same. However a comparison of the three varieties shows that an increase in the number of larvae would have soon reduced the mites to an insufficient density to support those predators. On R.C.H. a considerable number of eggs have been deposited, but the number of *M. ulmi* was not large enough to support the emerging larvae.

At the beginning of the second generation of beetles in the first part of August, it can be seen again that on R.C.H. eggs are deposited but no larvae succeed in thriving on the meagre supply of mites. Had there been more larvae on Mon. a more marked decrease in prey would soon have been followed by a starving of the predator, resulting in a situation as that on R.C.H.

When the larvae have died out we see that the remaining population on R.C.H. (in July) is sufficient to give a normal increase of *M. ulmi*, as is shown by the egg maximum of August 2nd being higher than the one of July 12th.



The increasing population of the predacious mite reduces the concentration of the prey after the middle of August. This increase of the predator goes on in spite of this which shows that even a very low concentration of prey is sufficient for the predator to remain alive. But even then there remain a few mites which escape the predator and outlive him.

We thus see that the mite which consumes far less prey than the beetle succeeds in reducing the prey much more effectively.

Now these observations and conclusions drawn from them lead to the following considerations.

In literature we generally find data about the significance of a predator in the form of the number of prey consumed per unit of time. This is a very superficial characterisation of the activity of the predator. The number of prey consumed per unit of time by one individual of the predator depends on a large number of factors, and is, amongst others, influenced to a large extent by the population-density of the prey. For different predators this influence will not always be parallel.

Other things being equal, in general the number of prey consumed per individual predator will be proportional to the number of prey present. In a certain medium range this proportionality will be a linear function, but at high and at low concentrations there will be digressions from the straight line.

If the population-density becomes very high the number of prey consumed by the predator will not increase any more, because there is a maximum number of animals it can cope with.

If, however, the population-density becomes very low, a certain limit will be reached below which the predator will not meet a prey frequently enough to enable it to keep alive. The predator will then die of starvation. Starting with the extremely simple theoretical case that a certain number of predators and prey are brought together in a relatively large space, without either of the two species multiplying, the relation between the population-density of the prey and the number of prey consumed by one individual of the predator per unit of time, can be expressed in a simple graph (fig. 1).

The amount consumed per time unit, by the predator A is limited by the values  $p$  and  $q$ , corresponding with a prey-concentration of  $a$  and  $b$  respectively. More than  $q$  cannot be consumed, and an increase of the concentration of the prey does not result in a higher consumption.

On the other hand  $p$  is the minimum ration for the predator on which it can remain alive; if there are a smaller number of prey than  $a$ , the chance of meeting its next prey in time becomes too small and the predator will starve. The number of prey consumed accordingly drops to zero.

At a different concentration of the predator a different situation will result. If there be twice as many predators the chance of a

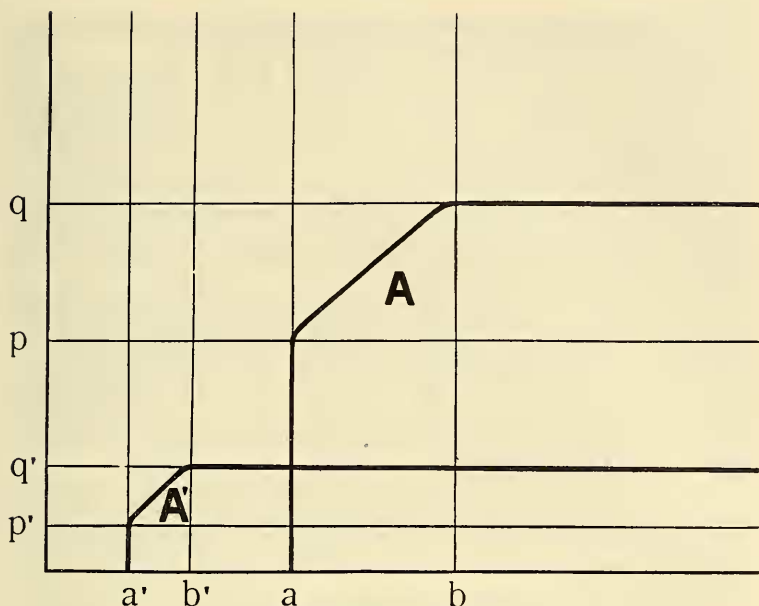


Fig. 1. Explanation see text.

prey being found and devoured is twice as great and the number will be reduced to half before starvation of all the predators. As, however, the predators are each of different disposition some will starve at a relative high  $a$ , that is, before the main body of predators has reached the stage  $p/a$ . This means a reduction of number of predators as the critical moment draws near, which will tend to increase the value of  $a$  at the moment of total disappearance of the predators. The difference in  $a$  is therefore much less than would be supposed from the difference in initial predator-concentration.

All the same, the value of  $a$  may vary more or less with the total concentration as will  $b$ , according to the same reasoning. The values of  $p$  and  $q$ , however, are independant of the concentration of the population, being a characteristic feature of a certain species of predator.

Under the given circumstances during the process of extermination of the prey the amount consumed by each predator runs along the line of the graph in a downward direction.

If the prey alone can multiply this will influence the speed of extermination and reduce it, or if the reproduction is quicker than consumption the process will be reversed, the prey increasing beyond the value  $b$ .

If the predator also increases this will have just the opposite

effect of increasing the speed of the process in downward direction (or reducing its upward trend as the case may be).

Under natural circumstances there will be a certain amount of immigration of predators, if the circumstances are favourable, and, if physically possible, emigration if the food resources run low. Also, of course the reproduction under favourable circumstances may increase considerably.

Now if two predators prey on the same species, the respective  $p$  and  $q$  values are likely to be different. In general a predator which can eat a lot (high value for  $q$ ) will have to eat a lot to remain alive (high value for  $p$ ).

This means that the ultimate destruction of prey to which the predator can go, is relatively poor, and there will remain a large number of prey at the moment the predator has disappeared.

A predator ( $A'$ ) which can only cope with few prey, (low  $q'$  value) as a rule will be able to live on very few meals too (low  $p'$ ) and consequently will clear up the prey much more efficiently before starving itself.

Or, the other way round, an increasing population of the prey will, at an early stage, be valuable food source for the  $A'$ -kind of predator, and only when it has increased to a much larger degree, will it be possible for the predator of the  $A$ -type to settle down amongst it.

The relation between  $p$  and  $q$  value is not simple, we can imagine them very far apart or close together. The further apart they are, the more important is the influence of the predator on the prey.

The relation between  $a$  and  $p$ , too is not simple. We can, for instance, imagine a high value of  $a$ , combined with a low  $p$  value in an animal which takes very long over consuming one prey, but which cannot go any length of time without having to find its next.

One more point should be made in this connection. It is obvious that the number of the little-eating type of predator must be large if it is to have a chance of reducing the population of the prey, while a relative small number of the voracious type will suffice to do the same.

We should now try to apply these theoretical considerations to the actual data reported in the first part of this article, and make a rough estimate of the values of  $a$ ,  $b$ ,  $p$  and  $q$  for the two predators of *M. ulmi*.

*Scimnus minimus*. On Mon. there is probably sufficient food for the first generation, on G.H.P. not quite enough because the number of larvae is considerably less than the number of eggs. The value for  $a$  will therefore be somewhere near 1000. The value for  $b$  cannot be derived from these data, but from observation on feeding animals it is probable that  $b$  is somewhere near 10.000.

The value for  $q$  can be derived from table 1, because these observations have, in all probability been made on well stocked leaves; it is probably somewhere about 25—30 per hour. For  $p$  no



definite data are available. Newcomer & Yothers found that a larvae had eaten 300—400 mites in 30 days, or 10—13 mites per day. This means that  $\frac{1}{2}$  mite per hour is sufficient for the larvae to grow up.

*Typhlodromus*. The decrease of mites in the autumn begins when the population of the prey is practically zero. The value for  $a$  is very near that, possibly about 5. The value for  $b$  can be approximated from the observation that the development on R.C.H. is less than on G.H.P. The value for  $b$  is therefore higher than 100. The higher population on Mon. has no further effect on the development of the predacious mite. Therefore the value for  $b$  is less than 500. It will probably be somewhere near 300.

From the data of Gilliat's the value of  $q$  can be put at more than 2, but  $p$  cannot be given. We can only say that it must be very small.

In tabulated form the results are thus :

	<i>Sc. minimus</i>	<i>Typhlodromus</i> spp.
$a$	1000	5
$b$	10000	300
$p$	$\frac{1}{2}$ p. hour	?
$q$	25-30 p. hour	2 p. day

Table 3.

It is only too obvious that these data cannot be more than approximations. They are sufficient, however, to show the very large differences between two species of predator. I hope some day to be able to get more reliable data from further investigations.

#### Summary.

Predators which can eat a lot of prey, generally must eat a lot to keep alive. They will starve when there are still a considerable number of prey present.

Predators which only eat little can also do with very little and are able to continue their persecution of the prey at very low population-density of this prey.

The relation between the concentration of the prey and the amount eaten by each of the predators can be expressed in a graph. (fig. 1). The critical values are :  $q$  which is the largest possible number of prey that can be consumed by one predator in a certain time, corresponding with the value  $b$  for the population-density of the prey. Further increase of the prey does not affect the value of  $q$ . At  $p$  we find the minimum on which a predator can live, corresponding to the concentration  $a$  of the prey.

The values for  $p$  and  $q$  are characteristic for each predator ; the values of  $a$  and  $b$  are to a certain extent dependant upon the concentration of the predator.

The higher  $a$  is the easier the prey will recover from the attack of the predator.

An actual example concerning the mite *Metatetranychus ulmi* as prey, and the much-eating predator *Scymnus minimus* and the little-eating predacious mite *Typhlodromus similis*, is discussed in detail and the critical values (fig. 1) are estimated (table 3).

Literature.

- Geyskes, D. C., 1938. Waarnemingen over het Fruitspint in verband met zijn bestrijding. Tijdschr. Plantenz., **44**: 49—80.
- Gilliat, F. C., 1935. Some predators of the European Red Mite, *Paratetranychus pilosus* C. & F., in Nova Scotia. Canad. J. Res., sec. D., **13** (1): 1—17.
- Listo, J. (†), Listo, E.—M., & Kanervo, V., 1939. Tutkimuksia hedelmäpupunkista (*Paratetranychus pilosus* C. & F.) (Studies on the Fruit Tree Red Mite (*P. pilosus* C. & F.)). Valt. maatal. julkaisuja = Agric. exp. activ. of the State, Helsinki, **99**: 143 pp.; Finnish with an English summary.
- Newcomer, E. J., & Yothers, M. A., 1929. Biology of the European Red Mite in the Pacific North West. U.S. Dept. Agric., Tech. Bull. **89**.
-